DIATOM ASSEMBLAGES FROM GOSHIKI-NUMA

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As with the larger lakes (Lakes Hibara, Onogawa and Akimoto) on the Urabandai Plateau, Goshiki-numa`s ponds and lakes were formed in 1888 following the last eruption of Mt. Bandai. However, unlike these larger circum-neutral lakes, many of the ponds within the Goshiki-numa system are weakly to strongly acidic (pH 3-6), although some are >pH7 (e.g. Lake Yanagi-numa). It is widely accepted that these acidic ponds receive their water supply from underneath Mt. Bandai itself, whereas the larger lakes are fed by the mountains to the north. Historical studies of the water characteristics of Goshiki-numa`s ponds and lakes are relatively few, but enough information exists to be able to reconstruct the pH changes over the last 70 years (Table I).

Location	Sampling date												
	① July 1931	② 16~20 Aug. 1935	③ 8 Sept. 1937	④ Aug. 1940	⑤ 13~16 Oct. 1952	⑥ 24 July 1964	⑦ 6~8 Aug. 1968	⑧ Aug. 1969	⑨ June 1980	⑩ Oct. 1986	⑪ 1988?	⑫ 1996?	⑬ June~Oct. 1996
Lake Aka-numa	4.1	3.3	3.0	3.5	4.0	3.9	3.9					3.4	
Lake Benten-numa	4.9	4.5	4.7	4.5	4.8	4.4	4.7					4.0-4.5	
Lake Ruri-numa	4.5	4.3	4.2	4.7	4.8	4.2	4.3				4.44	4.0	
Lake Midoro-numa		5.8	6.2	6.3	6.0	4.6	6.9					5.7	
Lake Ao-numa		4.4		4.7	4.8	4.1	4.2					6.5	
Lake Bishamon-numa	5.0	4.5-4.7	6.2	5.0	6.5	4.8	6.2		5.8-6.4	6.5	6.44		5.6-6.3
Lake Tatsu-numa		6.2	6.4		5.0	5.0-5.4		6.7				6.0	
Lake Yaroku-numa		6.5	6.6*	6.7	6.8	6.6	6.9						
Lake Yanagi-numa		7.2	7.1	7.3	6.9	5.3		6.7					

*6.3 in Yoshimura *et al.* (1936a)

Table I. Historical pH data from the Japanese literature on some of the Goshiki-numa lakes. References 1-3 were taken from Yoshimura *et al.* (1937), although Ref.1 (Yoshimura, 1932) and Ref.2 (Yoshimura *et al.*, 1936a) were the original papers. Other references include Negoro (1944; Ref.4), Fukushima (1964; Ref.5), Tanabe *et al.* (1964; Ref.6), Kato & Aita (1970; Refs 7 and 8), Tanaka (1992; Refs 9 and 10), Chiba (1988; Ref.11), Yoshitake & Fukushima (1996; Ref.12), and Sugawara *et al.* (1996; Ref.13).

Some of the earliest studies were conducted by Yoshimura (1932, 1935) and Yoshimura *et al.* (1936a, 1936b, 1937) who made limnological surveys of the lakes and ponds between 1931-1937. Later investigations were made by Negoro (1942, 1944, 1968, 1970), Fukushima (1964), Tanabe *et al.* (1964), Adachi (1969, 1970), Kato & Aita (1970), the JIBP-PF Research Group of acid lakes in Urabandai (1975), and Yoshitake & Fukushima (1996). More recently, detailed information on Lake Bishamon-numa has been reported by Sugawara *et al.* (1999). Many of these studies reported on the diatom species found in each lake. Here, a summary of the important species is presented in Table II.

Over the last 3 years a number of water and surface sediment samples have been collected from the various lakes within the Goshiki-numa National Park (Fig.1; Table III). The diatom assemblages within these samples have now been identified, photographed, counted, and compared with the physico-chemical data set (temperature, salinity, conductivity, pH, Fe^{2+}, Fe^{3+}) of each waterbody. The sample preparation methods have been discussed previously. Most of our physico-chemical measurements fall within the ranges of those taken by previous researchers. The dominant species found in each lake are given in Table III. In addition, two short gravity cores were taken in Lakes Bishamon-numa (5-7-1996; Fig.2) and Benten-numa (29-9-1997; Fig.3). The diatom assemblages within the Bishamon-numa core were previously reported by Shiono & Jordan (1997), but the data has been replotted here in order to compare the assemblages with those of the Lake Benten-numa core. The short cores have not been dated yet, but are presumed to cover most of the post-eruption period (1888-1996/7).
The historical pH data set for Lake Bishamon-numa (Table I) together with our pH values (Table III) show that the lake pH has moderately fluctuated over the last 70 years (pH 4.5-6.8), but appears to have been more stable (pH 5.6-6.8) since the late 1960`s. The diatom assemblages (Fig.2) do not show any major fluctuations throughout most of the core, however, in the top part of the core (samples 14-16) a change occurred, characterized by a sharp increase in the percentage of *Aulacoseira ambigua* (called *Aulacoseira* sp. in Shiono & Jordan, 1995; 1997). At present we are not sure why this change occurred, but it may be related to the shift in pH towards more circum-neutral

Location	Important diatom species			
	16~20 August 1935 Yoshimura *et al.* (1936)	August 1940 Negoro (1942)	August 1940 Negoro (1944)	13~16 October 1952 Fukushima (1964)
Lake Aka-numa		*Eunotia* sp. (= *E. levistriata* ?)	*Eunotia septentrionalis* var. *intermedia*, *E. s.* var. *levistriata*, *Pinnularia braunii* var. *amphicephala**	
Lake Benten-numa	*Asterionella*, *Melosira*‡, *Navicula*		*Asterionella formosa*	*Rhopalodia gibberula*
Lake Ruri-numa	*Asterionella*, *Epithemia*, *Fragilaria*		*Asterionella formosa*	
Lake Midoro-numa	*Asterionella*, *Melosira*‡, *Diatoma*			*Pinnularia subcapitata*
Lake Ao-numa	*Asterionella*, *Diatoma*, *Surirella*		*Asterionella formosa*	
Lake Bishamon-numa	*Asterionella*		*Pinnularia braunii* var. *amphicephala**, *Asterionella formosa*	
Lake Tatsu-numa	*Asterionella*, *Melosira*‡, *Surirella*			*Rhopalodia gibba*
Lake Yaroku-numa	*Asterionella*, *Tabellaria*, *Fragilaria*, *Diatoma*			*Fragilaria* sp., *Rhopalodia gibba*
Lake Yanagi-numa	*Asterionella*, *Melosira*‡, *Navicula*, *Fragilaria*			*Fragilaria* sp., *Rhopalodia gibba*, *Synedra ulna* var. *biceps*, *Mastogloia smithii*, *Epithemia turgida*

‡ These *Melosira* spp. are now probably *Aulacoseira* spp.
* This is probably a misidentification, and may be what is now called *P. acidojaponica* (Idei & Mayama 2001)

Location	Important diatom species		
	Negoro (1970)	JIBP-PF (1975)	Yoshitake & Fukushima (1996)
Lake Aka-numa			*Nitzschia capitellata*
Lake Benten-numa			*Eunotia exigua*, *Surirella* sp., *Nitzschia capitellata*
Lake Ruri-numa			*Eunotia exigua*
Lake Midoro-numa			*Aulacoseira* sp., *Melosira varians*, *Eunotia exigua*
Lake Ao-numa			*Fragilaria vaucheriae* var. *capitellata*, *Anomoeoneis neoexilis*, *Nitzschia obtusa* var. *scalpelliformis*
Lake Bishamon-numa			
Lake Tatsu-numa	*Melosira italica*‡, *Surirella tenera*, *Nitzschia obtusa*, *Fragilaria construens* var. *venter*, *Gomphonema gracile*	*Melosira italica*‡, *Melosira granulata*‡, *Nitzschia obtusa* var. *scalpelliformis*, *Nitzschia obtusa* var. *lapidula*	*Fragilaria* sp.
Lake Yaroku-numa			
Lake Yanagi-numa			

‡ These *Melosira* spp. are now *Aulacoseira* spp.

Table II. Historical diatom data from the Japanese literature on some of the Goshiki-numa lakes.

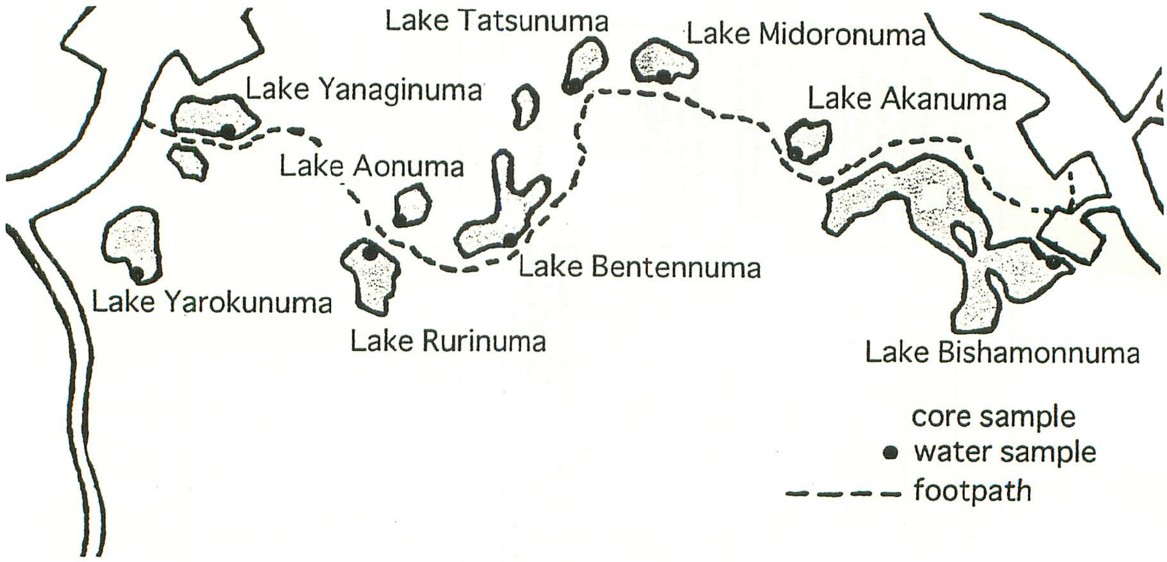


Figure 1. Map showing the water and core sampling point locations in the Goshiki-numa area.

Location	Sampling date	Temperature (°C)	pH	Dominant diatom species
Lake Aka-numa	1-10-1998	6.5-7.8	3.9	*Eunotia exigua* and *Pinnularia abaujensis*
	21-9-2000	14.2-14.8	3.8-4.1	
Lake Benten-numa	1-9-1997	15.2	4.8	*Surirella linearis* var. *linearis* and *Surirella* sp.1
	21-9-2000	22.3-23.1	4.1-4.5	
Lake Ruri-numa	1-9-1997	15.2	4.6	*Fragilaria* spp., *Brachysira brebissonii* and *Eunotia arcus*
	21-9-2000	21.3-22.1	4.5	
Lake Midoro-numa	1-9-1997	11.6	5.3	*Eunotia arcus*
	1-10-1998	11.3-12.0	5.4	
	21-9-2000	17.3-18.1	5.4	
Lake Ao-numa	1-10-1998	8.8-9.3	5.7	*Gomphonema* sp.
	21-9-2000	20.8-21.6	6.6	
Lake Bishamon-numa	1-9-1997	15.6	6.8	*Fragilaria* spp. and *Aulacoseira italica*
	1-10-1998	9.6-9.7	6.8	
	21-9-2000	21.6-22.7	5.9-6.2	
Lake Tatsu-numa	1-9-1997	13.4	7.2	*Fragilaria* spp. and *Aulacoseira italica*
	1-10-1998	10.3-11.2	7.0	
	21-9-2000	17.6-18.2	6.4-6.9	
Lake Yaroku-numa	21-9-2000	20.8-21.7	6.8-7.2	*Fragilaria* spp., *Cocconeis placentula* and *Gomphonema* spp.
Lake Yanagi-numa	1-9-1997	14.5	7.3	*Fragilaria* spp., *Rhoicosphenia abbreviata* and *Epithemia adnata*
	1-10-1998	9.2-10.0	7.2	
	21-9-2000	19.3-19.9	6.6-6.9	

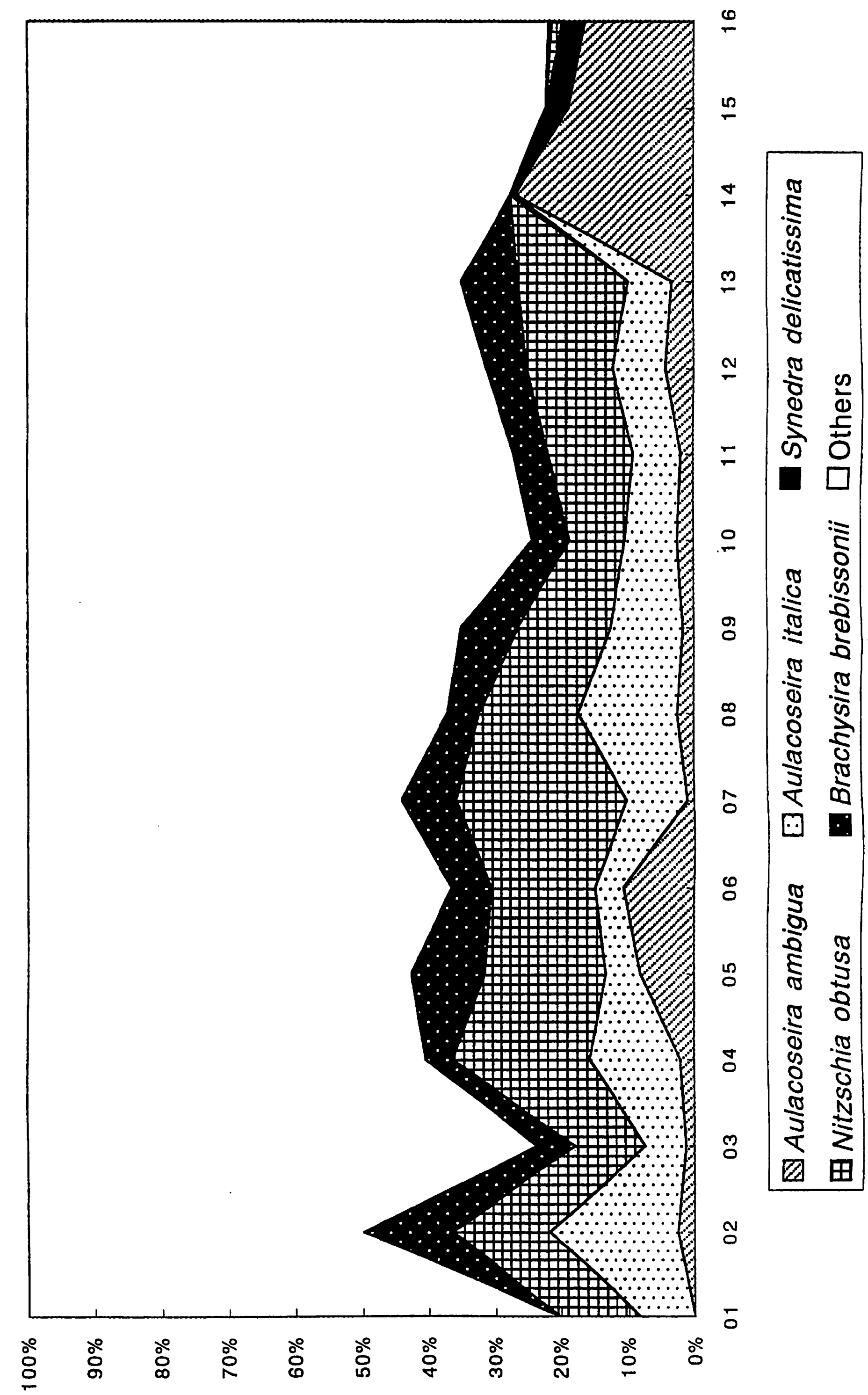
Table III. Physico-chemical and diatom data of some of the Goshiki-numa lakes collected during the present study.

conditions. Increases in *A. ambigua* percentages were also seen in Lake Hibara and Lake Onogawa core tops (Shiono & Jordan, 1997).

The historical pH data set for Lake Benten-numa (Table I) together with our pH values (Table III) show that the lake pH has hardly changed over the last 70 years. The diatom assemblages within our core (Fig.3) also reflect this general lack of pH change, however, at the bottom of the core (samples 01-03) a different flora existed. One can only speculate that these samples correspond to a deposition time before the historical data set began (i.e. prior to 1931). This early diatom assemblage is dominated by attached and benthic diatoms, whilst later samples contain high percentages of *Aulacoseira ambigua* and *A. italica*, both planktonic forms. This suggests that Lake Benten-numa was much shallower in the earlier years (i.e. shallower than the 6.7m reported by Yoshimura *et al.*, 1936a). The planktonic diatom assemblage of Lake Benten-numa in the summer of 1935 (Yoshimura *et al.*, 1936b) was dominated by *Asterionella*, whilst *Aulacoseira* (cited as *Melosira*) and *Navicula* (both important genera in our core) were rare. However, this could be interpreted as unrepresentative of the spring diatom bloom, which by August would have sunk out of the water column and would have been lying on the sediment surface.

In the future it is hoped that further limnological information can be gathered from Goshiki-numa and that more short cores can be taken and possibly dated. In this way it may be possible to design a local proxy-pH meter using the pH tolerances of living diatom assemblages, and to reconstruct past pH changes using the change in diatom assemblages downcore. At present the pH range of Goshiki-numa lakes lies between pH 3.8-7.3, however, the recent volcanic tremors on Mount Bandai (article in Japan Times, 1st January 2001) may indicate that the volcano is close to a small-scale eruption. If that happens, it may cause a decrease in the pH value of the source waters, and thus eventually of Goshiki-numa`s lakes. In order to develop the proxy-pH meter our present range needs to be extended by incorporating Lakes Akadoro-numa, Midori-numa and Mosen-numa (pH3.2-3.9) and the fumaroles near Nakanoyu Spa (JIBP-PF Research Group of acid lakes in Urabandai, 1975). A survey of acidobiontic diatom communities has already been carried out elsewhere (Lake Okama, Zao Spa, and Lake Katanuma) by our group, where it was shown that the diatom assemblages living in waters of pH1-3

Figure 2. The downcore changes in diatom assemblage in a Bishamon-numa core. Sample 16 represents the top of the core.



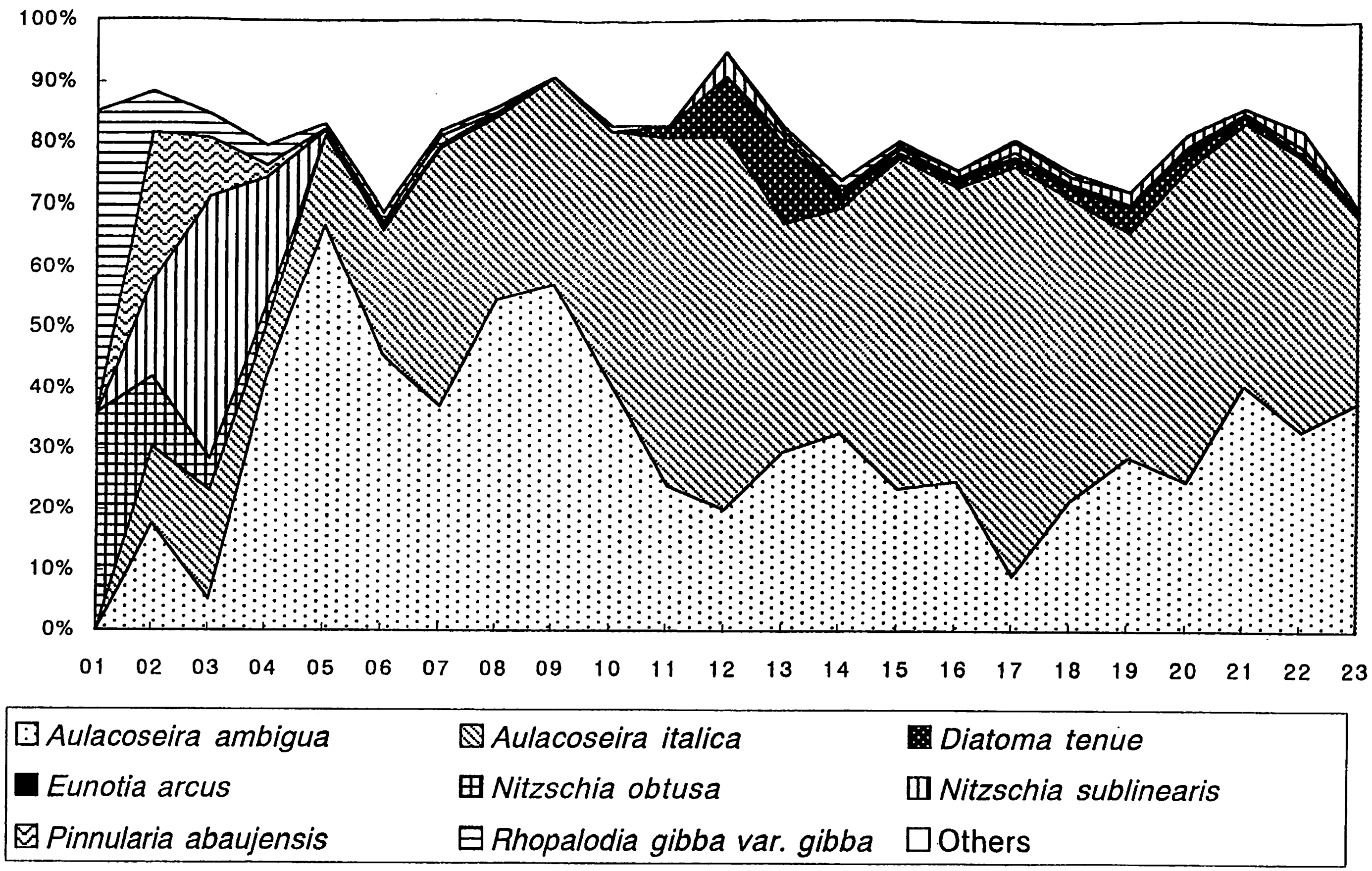


Figure 3. The downcore changes in diatom assemblage in a Benten-numa core. Sample 23 represents the top of the core.

are more specialized and less diverse (basically dominated by *Pinnularia* spp.) than those found in waters >pH3 (Jordan, 2001). In addition, the area around Banso Spa (pH 8.3; Chiba 1988), close to Lake Hibara, may provide us with slightly alkaline samples.

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3. 研究実績

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